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Drying of residual tilapia skin from filleting using a thermophotovoltaic solar dehydrator

Secagem da pele de tilápia residual de filetagem em desidratador solar termofotovoltaico

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ABSTRACT: Tilapia comprises one of the most cultivated fish species worldwide, mainly commercialized in the form of fillets. As a result, the amount of waste generated by processing is high, with tilapia skin being commonly discarded and not used as food for human consumption. In this context, the aim of this study was to dry residual filleted tilapia skins in a solar dehydrator and perform physical-chemical analyses after drying in order to evaluate the potential for the development of byproducts. The skins were collected at a fish market on Mercado do Peixe in Teresina - PI. Treatments consisted of four sodium chloride concentrations (0.0%; 25.0%; 50.0% and 100.0%), with five replications, totaling 25 samples. The skins were dried in the solar dehydrator for 24 hours, followed by moisture, ash, protein, lipids, pH and water activity analyses. Moisture in the *in natura* skins was 57.7%, differing significantly from the dehydrated tilapia skins, which ranged from 9.4% to 10.6%. The ash in the *in natura* skins was 0.17%, while dehydrated tilapia skins displayed variations from 1.19% to 4.17%. The crude protein found of the *in natura* skins was 41.4%, significantly different (P <0.05) from the skins submitted to the solar dehydration method. Based on these findings, the use of solar dehydrator for short periods is confirmed to favor the uniform dehydration of residual tilapia skin from filleting, generating a product with satisfactory bromatological patterns for the development of fish-based by-products.

KEYWORDS: *Oreochromis* sp. Reuse. Solid waste. Solar dehydrator.

RESUMO: A tilápia é uma das espécies de peixe mais cultivadas no mundo, sendo comercializada principalmente na forma de filé, com isso, a quantidade de resíduos gerada com o processamento é elevada, sendo a pele de tilápia comumente descartada e não aproveitada como alimento de consumo humano. Desta forma, o objetivo desse estudo foi aproveitar peles de tilápia residuais de filetagem e realizar análises físico-química após secagem em desidratador solar afim de avaliar seu potencial para desenvolvimento de coprodutos. As peles foram coletadas no Mercado do Peixe em Teresina - PI. Foram definidos os tratamentos, adicionando quatro concentrações de cloreto de sódio (0,0%; 25,0%; 50,0% e 100,0%), com cinco repetições, totalizando 25 amostras. As peles foram encaminhadas para secagem no desidratador solar por 24 horas. Depois, realizou-se as análises de umidade, cinzas, proteína, lipídios, pH e atividade de água. O teor de umidade encontrado na pele em natureza foi de 57,7%, diferindo significativamente das peles de tilápia desidratadas que variaram de 9,4% a 10,6%. O teor de cinzas encontrado na pele em natureza foi de 0,17%, enquanto nas peles de tilápia desidratadas houve uma variação de 1,19% a 4,17%. A proteína bruta encontrada nas peles da tilápia em natureza foi de 41,4%, diferindo significativamente (P < 0,05) das peles submetidas ao método de desidratação solar. Com base nos resultados observados nesse estudo, conclui-se que a utilização de desidratador solar em curtos períodos favorece a desidratação uniforme da pele de tilápia residual de filetagem, gerando produto com padrões bromatológicos satisfatórios para o desenvolvimento de coprodutos à base de pescado.

PALAVRAS-CHAVE: *Oreochromis* sp. Reaproveitamento. Resíduo sólido. Desidratador solar.

INTRODUCTION

Modern society has increasingly demonstrated greater concerns for health and the environment, especially due to the negative environmental impact that industrial activities can cause. In this context, the food industry has sought to supply consumer desires for healthier, fresher, palatable products, microbiologically safe and free of additives, investing in innovative "clean" technologies, which maintain desirable food

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characteristics without harming the environment (TOEPFL et al., 2006; PIRES et al., 2014).

In 2019, Nile tilapia production represented 57% of all Brazilian fish farming, of great importance for the country's economic and food sectors (BRASIL, 2020). Processing companies generate significant amounts of waste with tilapia processing, comprising about 70% of the volume processed, which is not always used (LEONEL, 2016). Fish waste includes all leftovers from processing, such as head, bones, skin and viscera, among others, which contain high protein, mineral and lipids contents (STEVANATO et al., 2007; SILVA et al., 2009). The environmental and economic sustainability of this production chain depends on the use of this generated waste.

Fish skin represents an average of 7.5% of the total fish weight (FRANCO, 2013; YOSHIDA et al., 2016), and can be used to produce leather and gelatine. However, due to its high sensitivity to bacterial and autolytic degradation, fish skin must be correctly stored and distributed in order to preserve its quality. To this end, both cold or dehydration can be applied to inhibit microbial development (SOUZA, 2004; BORDIGNON et al., 2012; EUGÊNIO, 2018).

Dehydration can be accomplished through forced air circulation using heat, generated by wood and oil pyrolysis and electrical energy. The use of non-polluting renewable sources to generate energy has become an ecologically viable alternative for this process, especially in regions with favorable environmental conditions. Different types of solar dryers are available, and indirect exposure dryers display the advantage of protecting food against direct sun exposure, resulting in better quality products (NASCIMENTO et al., 2015).

Solar energy applied in food dehydration displays several sustainable characteristics, such as being renewable, releasing no waste into the atmosphere and displaying great potential, in addition to being widely available in almost all of Brazil, especially in the Northeast (MACHADO; MIRANDA, 2015).

Considering the relevance of the waste generated by fish filleting that can be transformed into fish-based byproducts, with consequent decreases of environmental impacts, alternative ways to use this raw material for human consumption are required. In this context, the aim of this study was to dry residual filleted tilapia skins in a solar dehydrator and perform physical-chemical analyses after drying in order to evaluate the potential for the development of fish-based byproducts.

MATERIAL AND METHODS

Tilapia skin sampling

The samples were acquired directly from fish market traders on Mercado do Peixe in Teresina - PI that fillet tilapia (*Oreochromis* sp.) and discard the skins after processing. The samples were packed in plastic bags and transported in isothermal boxes containing recyclable ice to the Fish Technology Laboratory.

Sample preparation

At the Fish Technology laboratory, the scales were removed from the skins with the aid of a manual metal extractor and discarded. The skins were then washed under running water, cut into 5.0 cm x 3.0 cm pieces and, finally, immersed in hyperchlorinated water containing 5.0 ppm of free residual chlorine for 10 minutes.

Salting and dehydration

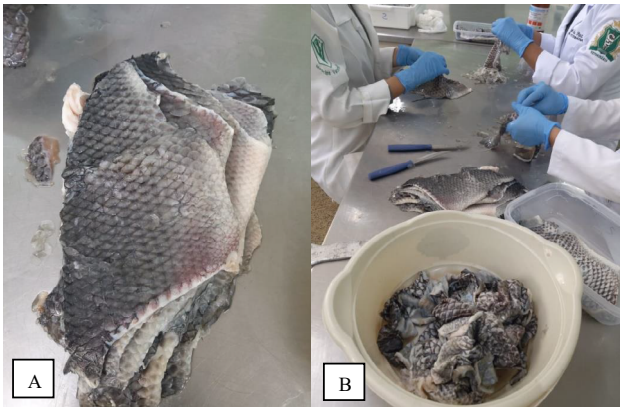
After preparing the skins, the salting and drying treatments were defined as follows: control group (*in natura*, without sodium chloride addition and without undergoing the dehydration process) and four sodium chloride treatments (0.0% ; 25.0%; 50.0% and 100.0%) followed by the dehydration process, comprising five repetitions, totaling 25 samples.

Direct sodium chloride addition was performed uniformly on the surface of each sample. The skins were then placed on drying trays in an indirect exposure Ecodrytec 216GII Thermo-photovoltaic Solar Dehydrator, where the air is heated in the collector and being blown into the chamber where dehydration by natural convection or with the aid of a fan is performed for 24 hours. The control group samples were immediately analyzed at the Physical-Chemical Food Control Laboratory. After drying, the samples from the sodium chloride treatments were sent to the laboratory for analysis.

Solar dehydration

The solar dehydrator used to dry the samples (Figure 2) displays an internal capacity of 216 liters and measured 200x180x700 cm, built in sheet metal, consisting of eight stainless steel shelves, totaling a useful area of about 3.0 m².

The device does not require electricity or gas to function and works under clear to partially cloudy sky condition. No integrated system for measuring and recording temperature



Source: Personal archive (2019).
Figure 1. Tilapia skins collected at Mercado do Peixe in Teresina - PI (A) Removal of scales for sample preparation (B).

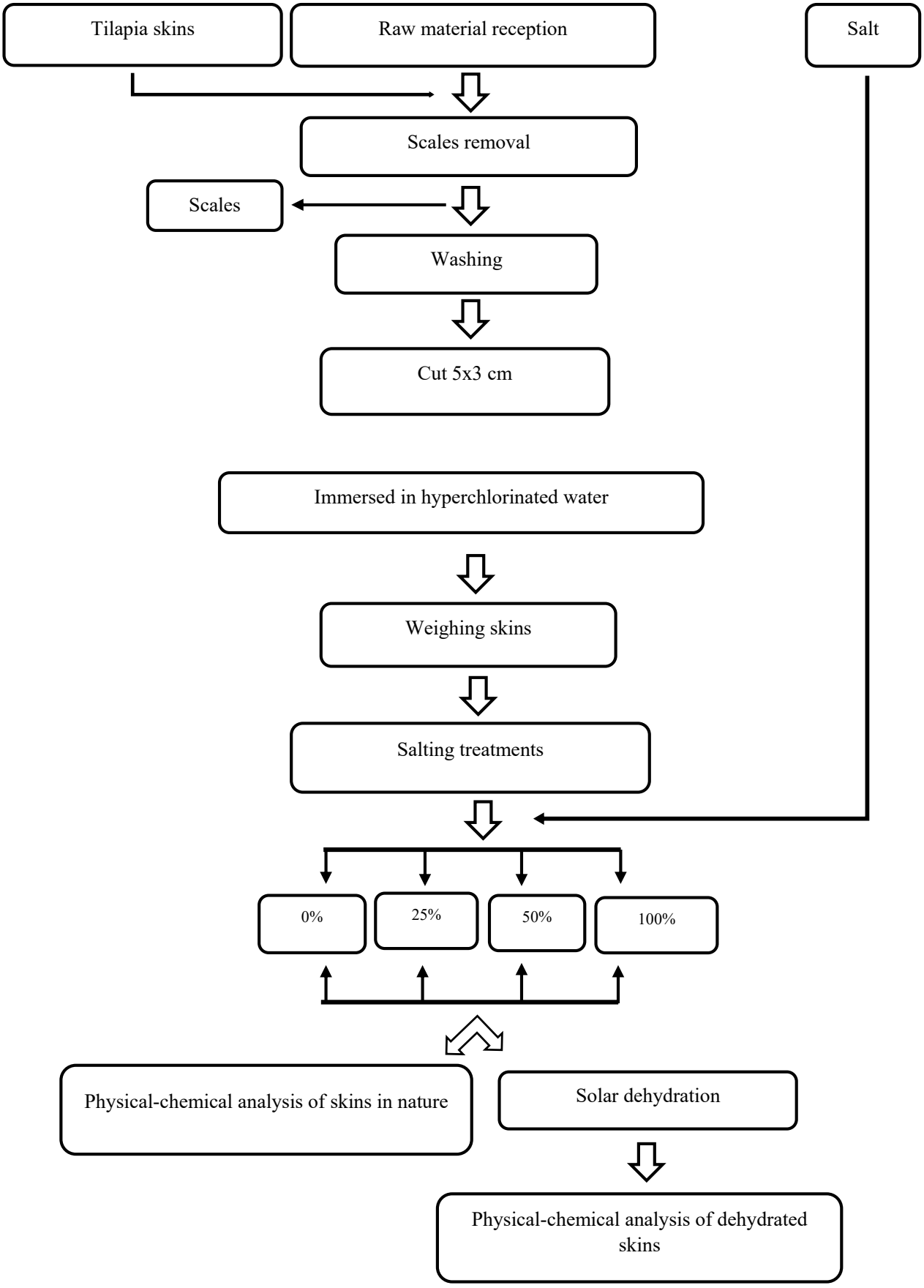


Figure 2. Flowchart demonstrating the process of dehydrating the tilapia skin

parameters or relative humidity is available. The operating temperature range varies from 40 °C to 80 °C and the forced ventilation is controlled with an analog flow control system by a potentiometer.

Dehydration took place in September 2019. The samples were placed in the solar dehydrator in the morning, at around 9:00 am, and removed the next day, at the same time, totaling 24 hours in the solar dehydrator.

The climatic conditions of the municipality of Teresina-PI (latitude-5.2403, longitude-42.67914) in September 2019 were obtained directly from the Climatempo site, which provides climatological forecasts, as follows: minimum temperature of 22 °C, maximum temperature of 36 °C and 9.0 mm precipitation (Figure 3) (CLIMATEMPO, 2019).

Physicochemical analyses

The following physicochemical analyses were carried out at the Núcleo de Estudos Pesquisas e Processamento de Alimentos (NUEPPA), Physical-Chemical Food Control Laboratory: moisture content, ash, protein, lipids, pH and water activity. All analyses were performed in triplicate.

Moisture content determinations

Tilapia skin moisture content was determined by the method based on weight loss after heating and water removal (AOAC, 2016). This method consists of direct heating of a 2.0 g sample in a porcelain capsule in an oven at 105°C for three hours, until reaching constant weight. The samples were subsequently placed in the desiccator for cooling and weighed for the calculations to be performed.

Ash determinations

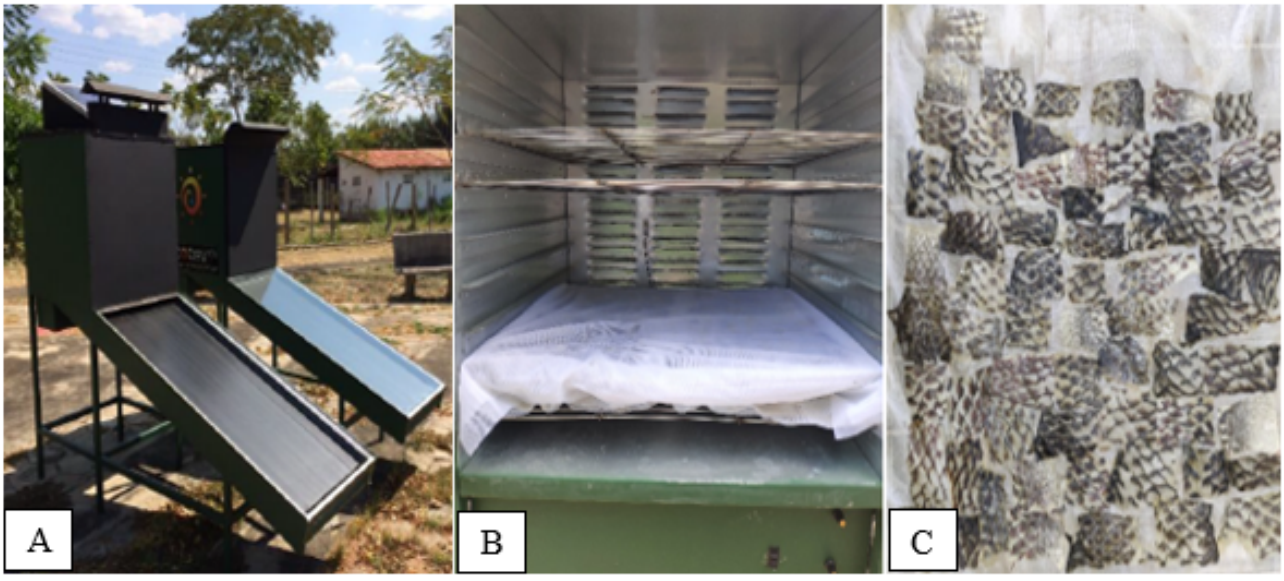
Ash contents were determined by the incineration method, consisted of carbonizing and incinerating a 2.0 g sample in a muffle furnace at 550°C for four hours, in a previously tared porcelain capsule, until complete coal removal. This results in a white or slightly gray ash, which is then placed in a desiccator to cool for one hour, and weighed for the calculations to be performed (AOAC, 2016).

Protein determinations

Protein determinations was performed using the micro-Kjeldahl method. With the aid of an analytical balance, approximately 0.25 g of each sample were weighed and transferred to a tube, followed by the addition of 2.5 g of a catalytic mixture and 7.0 mL of sulfuric acid and heating in a digestion block until obtaining a clear and transparent liquid, with a blue-green tint, characterizing the sample digestion. In this method, organic nitrogen is transformed into ammonia and organic components are converted into CO_2 and H_2O. This is followed by distillation out, which consists of collecting the ammonia gas released in the receiving solution (boric acid) and, finally, titration, when the quantitative determination of the ammonia contained in the receiving solution (boric acid) is carried out (AOAC, 2016).

Lipid determinations

The amount of lipids present in the tilapia skin samples was determined by the Soxhlet method, where 2.0 g of each sample were weighed, packed in filter paper and taken to the extractor. The extraction process took place over six hours, using petroleum ether as solvent (AOAC, 2016).



Source: Personal archive (2019).

Figure 3. Solar dehydrator Photovoltaic term Ecodrytec (A) Distribution of samples in the dehydrator (B) and samples after dehydration process (C).

pH determinations

The pH analyses were performed with the aid of a bench MPA-210 MS Tecnopon Instrumentação pHmeter. Briefly, 10 g of each sample were weighed and placed in a beaker-type flask containing 100 mL of distilled water. The electrode was then introduced in the middle and the results were obtained after reading stabilization (AOAC, 2016).

Aw determinations

The water activity (Aw) analyses were performed using a portable Decagon Devices Pawkit sensor. Briefly, 3.0g of each sample were placed in a plastic container attached to the sensor, and the result was obtained directly from the device.

Statistical analyses

An Analysis of variance (ANOVA) was performed, applying the Holm-Sidak test to compare the variable means, adopting a significance level of P = <0.001, using the Sigmastat 4.0 software.

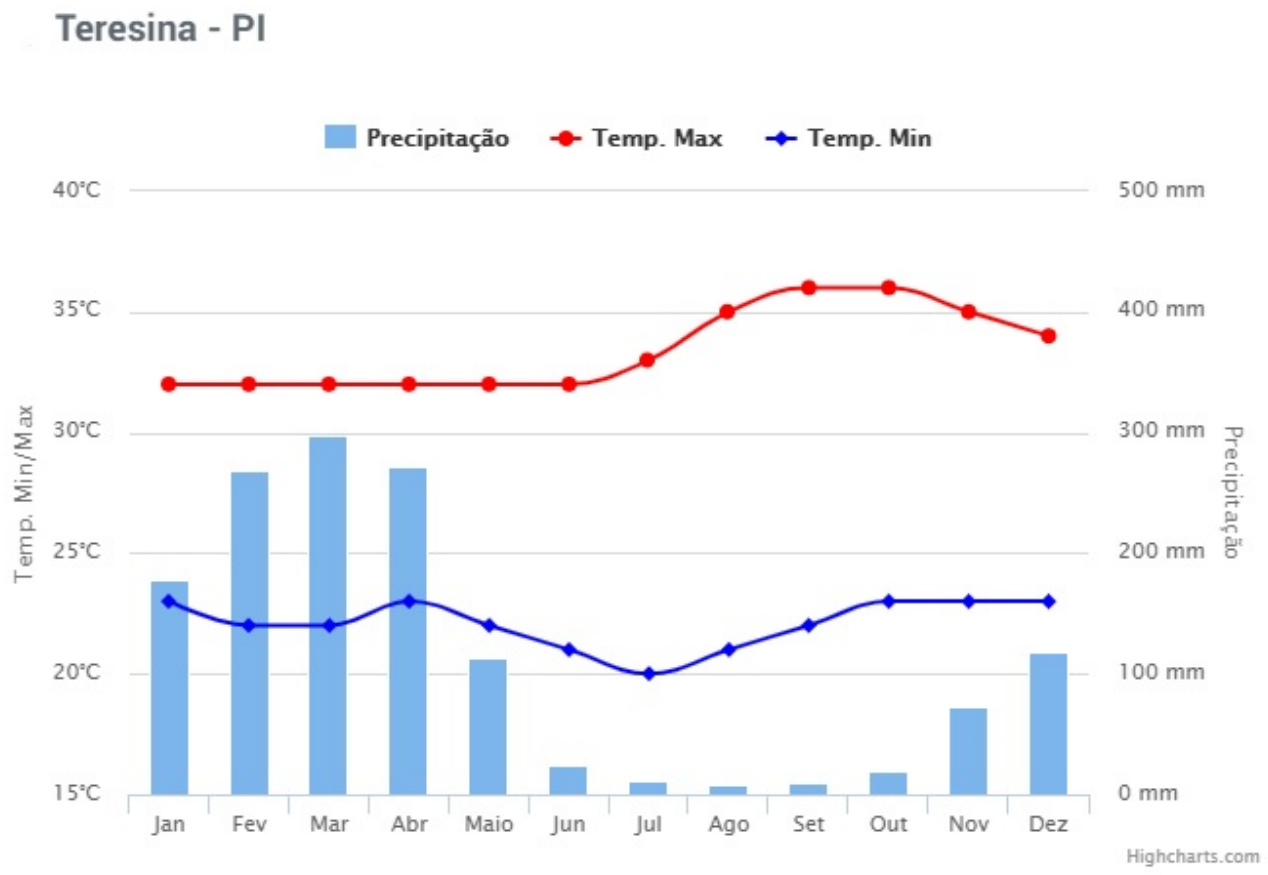
RESULTS AND DISCUSSION

The average room temperature during the experiment was of 36°C. With this, the solar dehydrator performance reached up to 80°C with hot air circulation. According to Celestino (2010), the ability to eliminate water from a food item depends, mainly, on temperature and relative air humidity. Table 1 presents the results of the centesimal tilapia skin composition analysis for the *in natura* (control) samples and those submitted to solar dehydration following different sodium chloride treatments.

The moisture content of the *in natura* skins (control) was 57.7%, significantly different from the dehydrated tilapia skin content, which ranged from 9.4% to 10.6%. The different washing and preserving methods prior to processing may also influence tilapia skin moisture content, especially concerning the drying time after the process. The differences observed between the *in natura* and dehydrated skins are due to the dehydration process, that causes moisture and mass losses. About 100 g of each skin sample was used for each treatment, decreasing to 35 g after the dehydration process.

The ash content of the *in natura* skins was 0.17%, while the dehydrated tilapia skins exhibited variations from 1.19% to 4.17%. The ash content increased gradually in the sodium chloride treated dehydrated skins. Bordignon et al. (2012) reported an ash content for frozen tilapia skins of 1.44% and for slated skins of 2.06%, similar to the values observed herein. This difference is probably due to differences between the two sodium chloride addition methods.

The Nile tilapia skins were not significantly different concerning lipid content between treatments (P = <0.001), with averages



Source: Climatempo (2019).
Figure 4. Climatic conditions of the city of Teresina-PI in 2019.

Table 1. Average and standard deviation of the results of physical-chemical analyzes of samples of tilapia (*Oreochromis* sp.) Skins *in nature* and dehydrated with different percentages of sodium chloride.

Parameters analyzed	Skin in nature (Control)	Dehydrated skin (Treatments with sodium chloride%)			
		0%	25%	50%	100%
Moisture (%)	$57.7^{a} \pm 4.1$	$10.0^{b} \pm 1.6$	$9.4^{b} \pm 1.9$	$9.8^{b} \pm 2.2$	$10.6^{b} \pm 1.8$
Ash (%)	$0.2^{c} \pm 0.03$	$1.2^{bc} \pm 1.16$	$2.0^{b} \pm 0.49$	$2.5^{b} \pm 0.85$	$4.2^{a} \pm 1.0$
Lipids (%)	$10.4^{a} \pm 2.9$	$13.0^{a} \pm 3.5$	$15.3^{a} \pm 4.1$	$14.3^{a} \pm 1.9$	$13.7^{a} \pm 5.1$
Protein (%)	$41.4^{b} \pm 1.2$	$81.9^{a} \pm 10.4$	$84.7^{a} \pm 4.0$	$78.5^{ab} \pm 8.3$	$75.0^{ab} \pm 6.2$
pH	$6.7^{a} \pm 0.18$	$6.9^{a} \pm 0.53$	$6.6^{a} \pm 0.56$	$6.6^{a} \pm 0.62$	$6.7^{a} \pm 0.72$
Aw	$0.8^{a} \pm 0.00$	$0.4^{b} \pm 0.07$	$0.4^{b} \pm 0.08$	$0.4^{b} \pm 0.08$	$0.4^{b} \pm 0.08$

Means on the same line followed by different letters differ from each other by the Holm-Sidak test (P = <0.001). Data expressed as mean ± standard deviation.

ranging from 10.4% to 15.3%. The lipid content of the *in natura* skins were the lowest, while the lipid contents of the skins submitted to the solar dehydration method were higher. The dehydration process probably resulted in nutrient sample concentration. Bordignon et al. (2012) reported lipid values between 19.0 g kg-1 (1.90%) and 22.6 g kg^{-1} (2.26%), higher than those observed in the present study, for frozen and salted Nile tilapia skins.

The crude protein content of the *in natura* skins (control) was 41.4%, differing significantly (P = <0.001) from skins submitted to the solar dehydration method, which presented higher and similar values. Ferreira et al. (2015) reported crude protein values of 18.2% and 19.6% in Nile tilapia skins preserved by freezing and dry salting, in contrast to Bueno et al. (2011), who reported protein tilapia skin gelatin values of 89.4% and 88.9%. These variations may be due to dehydration, that tends to concentrate nutrients due to water removal.

No significant differences between treatments were observed for pH, with averages ranging from 6.68 to 6.94. As samples were in accordance with the Brazilian legislation, which recommends a fish meat pH of less than 7.00 (BRASIL, 2017).

The water activity values of the *in natura* skins was 0.86, differing significantly from dehydrated tilapia skins, which ranged from 0.39 to 0.40. These differences are due to the dehydration process, that results in water loss. The sodium chloride concentrations did not affect tilapia skin moisture contents or water activity (Table 1). Therefore, dehydration was influenced only by the use of the solar desiccator.

According to Souza Filho, et al., (2012), microorganisms generally grow on substrates displaying water activity between 0.90 and 0.99, while yeasts and mycelial fungi usually grow in water activity ranging from 0.86 to 0.88, and some filamentous fungi are able to grow in water activity of up to 0.80. Therefore, the water activity of the dehydrated tilapia skins indicates adequate stability, inhibiting microbiological multiplication and increasing conservation periods.

CONCLUSION

The use of the solar dehydrator for short periods of time favors the uniform dehydration of residual filleting tilapia skins, generating a product displaying satisfactory bromatological standards. Therefore, we conclude that this type of waste displays potential for the development of fish-based byproducts, depending on the processing technique. This is, thus, a viable alternative from an economic and environmental point of view, applying a renewable and clean technology.

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